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FISH HANDLING PILOT STUDY
PICKERING NGS AND NANTICOKE TGS
Report No 87-189-K

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ABSTRACT

The effectiveness of experimental intake-forebay fish handling systems incorporating pneumatic poppers, air bubble curtain, filtered mercury vapour lights and Hidrostal pump and fish transfer system were evaluated. Pneumatic poppers operated at Nanticoke TGS CCW pump screenwells did not significantly reduce fish impingement. Low intake flow rates at the Pickering NGS 'A' skimmer wall prevented evaluation of fish avoidance of the popper at the wall. The three most effective attraction systems used mercury vapour lights to illuminate the Hidrostal fish pump intake and immediate area outside the intake mouth. The most effective attraction system used an air bubble curtain in combination with mercury vapour lights. No significant variation was determined between pump alone and all attraction systems. Cavitation problems limited pump operation with a 15 cm square clear intake to 600 RPM. This produced an effective 15 cm capture zone at the intake mouth. Alewife suffered slight scale loss during transport. The injury rate increased in larger fish species (60%). The use of a fish pump with clear intake and mouth area illuminated by mercury vapour lights is recommended. Each installation must be designed for a specific forebay after reviewing current, siltation, and fish concentration patterns within the forebay. A bubble curtain may be added if current and sediment conditions permit.

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EXECUTIVE SUMMARY

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At the request of Environmental Studies and Assessments Department a pilot scale fish handling study was conducted in the forebays of Pickering NGS and Nanticoke TGS. The fish handling system included pneumatic poppers to repel fish and a Hidrostal pump to transfer fish back to the lake. An air bubble curtain and mercury vapour lights were employed to lead and/or attract fish to the pump intake.

Although originally proposed to conduct the entire study at Pickering NGS, one aspect of the study (poppers) was transfered to Nanticoke TGS due to low fish densities and minimal station operation at Pickering NGS. In addition to low operation levels at Pickering, continuing equipment problems with the fish transfer system led to numerous delays in this aspect of the program.

Although initial tests of the poppers at the Pickering NGS 'A' skimmer wall and at a CCW screenwell at Pickering NGS 'B' indicated that alewife dispersed from the area of the popper when it was operating, subsequent tests at screenwells in the Nanticoke TGS indicated that the popper was ineffective in reducing the number of fish impinged on the travelling screens (at least under our experimental design).

The Hidrostal pump was effective in the live collection of fish. Although there was no signifcant differences in the rate of fish capture by the pumps among the various configurations of attractants, the system with mercury vapour lights to attract fish to the pump intake and an air bubble curtain to guide the fish toward the pump was on average the most effective system for fish capture.

For a forebay fish handling system a Hidrostal pump with attractants for the live transfer of fish back to the lake is recommended. Use of poppers to keep fish out of the CCW screenwells, however, appears to be ineffective.

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To Mr. C.W. Dawson
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FISH HANDLING PILOT STUDY
PICKERING NGS AND NANTICOKE TGS

1.0 INTRODUCTION

Capitalized Once-Through Cooling Program (COTC) studies (OHRD Reports 82-295-K, 82-362-K, 83-266-K, 83-54-K and 83-142-K) and related investigations (OHRD Reports 83-250-K and 85-258-K, ESEERCO Report EP-1 83-12) have demonstrated the potential use of various techniques to repel, guide, concentrate and transport fish in a viable condition. The objective of this study was to develop an environmental protection system capable of reducing fish impingement on travelling screens and transporting forebay entrapped fish back in to the lake in viable condition. To meet the objectives an intake-forebay fish handling system was designed incorporating pneumatic poppers, air bubble curtain, mercury vapour lights and Hidrostal pump transport system. The system was to be evaluated at the Pickering NGS intake-forebay. The study was conducted at the request of Environmental Studies and Assessments Department as part of the COTC Program.

2.0 METHODS

2.1 Fish Exclusion with Pneumatic Poppers

1. Skimmer Wall Port

Single pneumatic poppers (Bolt Technology Corporation Life Management System Model 10 Air Gun) were placed on the concrete abutments on either side of the western Pickering GS 'A' skimmer wall port. The poppers were operated at a rate of 15 pops per minute at 3 000 pounds per square inch (psi) pressure. Air pressure was supplied by a 7.5 cubic foot per minute gasoline compressor. A removable 2 m diameter trawl net was suspended in the skimmer wall port 4.6 m below the water surface during experimental and control replicates to sample fish moving through the port. Popper effectiveness was to be based on variation between experimental and control fish catches.

2. Condensor Cooling Water (CCW) Pump Well

Although it was initially proposed to evaluate the effect of poppers on fish impingement on Unit 8 of Pickering NGS 'B' in spring/early summer, fall and winter, testing was shifted to Nanticoke TGS after the apparatus was set up when concerns were expressed regarding potential effects of the studies on station operation at Pickering.

The postponted popper tests were conducted at Nanticoke TGS from mid November to early December. The two pneumatic poppers were suspended at mid depth outside the Unit 5 and 6 screenwell bar screens as required. The poppers were operated for 55 minutes at 15 pops/minute at 3000 psi. Screens were run manually for one half hour prior to the first test. Screens were then run for 5 minutes at the end of each test to evaluate the effectiveness of the poppers in excluding fish.

Experimental and control replicates were run simultaneously using:

a) Unit 5 screenwell as the experimental and Unit 6 screenwell as the control (17 tests).

b) Unit 5 screenwell as the control and Unit 6 screenwell as the experimental (6 tests).

Alternating experimental and control test replicates (7 test, 8 control) were also conducted within Unit 5 screenwell. This test configuration was not effected by possible fish abundance differences within unit screenwells. Replicate results were compared on a temporal basis using 2 way analysis of variance (ANOVA, $P<0.05$) with untransformed and log transformed data.

2.2 Fish Transfer with Hidrostal Pump

A Hidrostal Fish Pump (Model G12F-S) was submerged in the south-east corner of the Pickering NGS intake-forebay in an area of low current velocity (visual observation) in October 1984 (Appendix A, Figure 2.2-1). A 0.3 m semi-flexible intake hose extended 6.1 m from the pump down the intake channel slope to a clear plexiglass cone 1.0 m x 1.0 m square at the mouth tapering to a 0.5 m square at the cod end. The cone rested in 2.4 m of water. The intake cone system was subsequently modified following laboratory pump studies (OHRD Report 84-207-K) and Bruce NGS 'A' pump studies (OHRD Report 85-258-K). The cone was replaced in December 1984 with a clear acrylic intake tube 0.3 x 0.3 x 1.5 m to increase the effective velocity at the distal end of the intake system. The mouth of the new intake tube was situated approximately 1 m above the forebay bed and 1.4 m below water level.

The Hidrostal pump discharge system led from the pump through 0.3 m diameter semi-flexible hose to 0.3 m diameter PVC pipe. The PVC pipe extended 24.4 m up the side of the forebay channel groyne to a round 5.5 m x 1.2 m deep, above ground swimming pool constructed on top of the south groyne. A screened 0.3 m discharge pipe led from the swimming pool to Lake Ontario. After the February 1985 pump tests the swimming pool was replaced with a rectangular fiberglass tank (1.5 x 6.6 x 0.9 m deep) on loan from Bruce GS 'A' and Radioactivity Management and Environmental Protection Department (RMEP).

Preliminary tests indicated the capabilities of the pump hydraulic system and electric motor were insufficient to permit the pump to deliver the required water volume (Appendix A) even when operated at the maximum 1000 RPM. The discharge system was therefore repositioned northeast of the original site closer to the forebay water level (Figures 2.2-1, 2) in June and July. This reduced the discharge head from 7.6 m to 3.0 m.

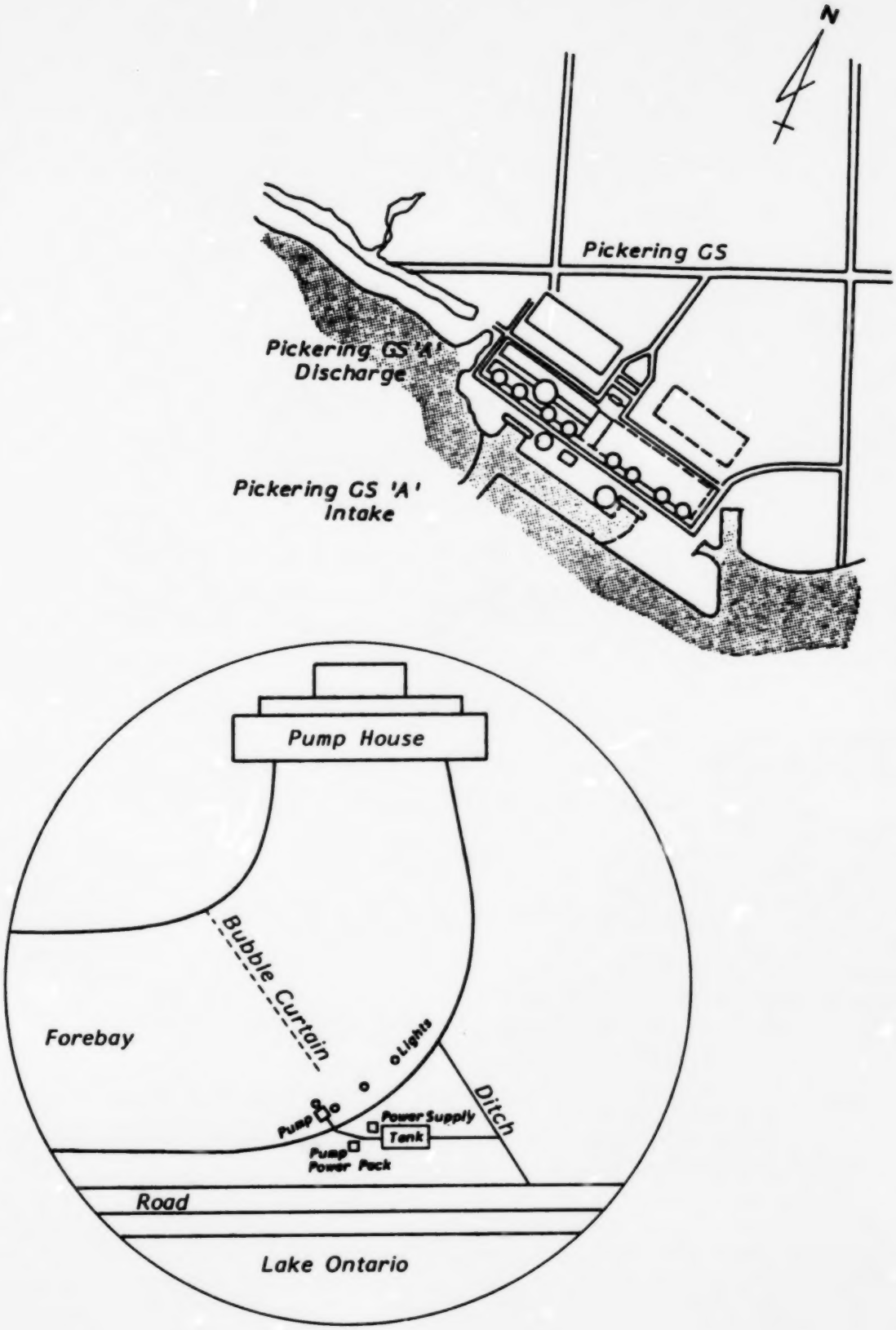


FIGURE 2.2-1
FISH HANDLING PILOT STUDY LOCATION
PICKERING NGS

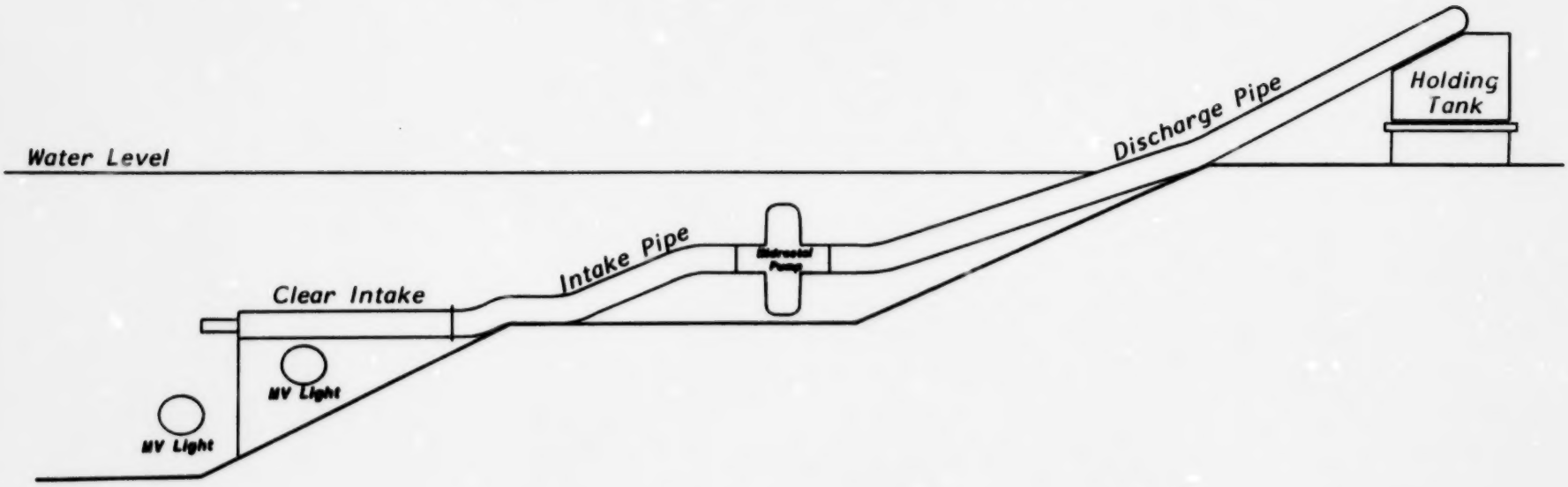


FIGURE 2.2-2
PICKERING FISH HANDLING PILOT STUDY
PUMP SYSTEM DESIGN

Six daylight tests were performed with the pump operating at 800 RPM. The opening of the intake tube was then reduced to 0.15 x 0.15 m with the addition of a clear acrylic adaptor to increase intake current velocity. The Hidrostal pump was operated at the recommended speed of 800 RPM (OHRD Report 82-295-K) during preliminary system tests. The intake pipe collapsed after 5 minutes of operation at this speed. Tests were conducted at 600 and 700 RPM after the intake pipe was replaced. The intake pipe twisted and the Hidrostal pump cavitated at 700 RPM. No problems were encountered during the 600 RPM tests. All future tests were conducted at 600 RPM.

Four filtered mercury vapour lights were installed to lead and or concentrate fish near the mouth of the pump intake (Figures 2.2-1,2). One light illuminated the inside of the cone, one illuminated the area immediately outside the mouth of the cone while the remaining two lights illuminated areas 10 and 20 m to the east of the pump. The mercury vapour lights were filtered to reduce light transmission in the non-blue range of the spectrum.

An air bubble curtain was installed at approximately 30 degrees to the intake-forebay water flow from the north side of the forebay towards the Hidrostal pump intake (Figure 2.2-2). The bubble wands were constructed to permit air to escape evenly along the entire length of the wand (OHRD Report 84-310-K). Compressed air was supplied from the Pickering service air system at 500 kPa.

Test design configurations are presented in Table 2.2-1. Ten 1-2 h replicates were to be conducted during the day and night in each of the spring/early summer, fall and winter seasons. Late delivery of the Hidrostal pump, base and hoses prevented testing of the system in the summer or fall of 1984. Problems with the hoses and Hidrostal pump (Appendix A) prevented tests in December 1984 and February 1985 during the winter period. Six night tests of each design replicate were completed in July and August 1985. Tests were terminated due to low fish numbers in the intake/forebay. Six day tests were also performed. However, further day tests were cancelled due to the low fish abundance. Fall 1985 tests were cancelled after reviewing the July and August test results when low fish numbers were present in the forebay.

The effectiveness of the fish transfer system was based on the number of fish passed by the pump per hour. Test results were compared using one way analysis of variance (ANOVA) with untransformed and log transformed data.

Evidence of injury or death among fish was recorded for each replicate. Latent mortality (24 h) was to be determined twice each week on a sample of 50 fish of the most common species passed by the pump relative to 50 fish of the same species collected by netting. Only one latent mortality (16 h) study was conducted due to the rapid decrease in numbers of fish in the forebay.

A gill net was to be set for 2 hours during the day and night once each week to determine the effectiveness of the fish pump relative to species present in the intake/forebay. The gill net sets also indicated relative fish abundance in the intake/forebay channel. One 122 m experimental gill net (8 pannels, 3.8 - 12.7 cm stretched mesh 1.27 in cm increments) was set in the channel. Further gill net sets were cancelled due to the low fish abundance in the intake/forebay channel.

TABLE 2.2-1

HIDROSTAL PUMP DESIGN CONFIGURATIONS PICKERING NGS, 1984-1985

CONFIGURATION	LIGHT OPERATION
A - pump alone	no lights
B - pump with cone light	cone light continuously on
C - pump with cone light and outside light	cone light continuously on, outside light extinguished for 5 minutes at 10 minute intervals
D - pump with cone light, outside light and sequential lights	cone light continuously on, remaining lights initially on, sequentially extinguished at 5 minute intervals, then repeated after last light extinguished for 5 minutes
E - pump with cone light and bubble curtain	cone light continuously on
F - pump with cone light, outside light and bubble curtain	cone light on continuously, outside light extinguished for 5 minutes at 10 minute intervals

3.0 RESULTS

3.1 Fish Exclusion with Pneumatic Poppers

1. Skimmer Wall Port

Tests at the skimmer wall were attempted during the weeks of June 17 and 24. Three day and night tests and three controls were conducted each week. In all cases the total fish catch was 0. Large numbers of fish, primarily alewife (Alosa pseudoharengus), were observed near the surface in close proximity to the skimmer wall at the start of each night replicate. Alewife were observed to disperse to an area 20 m east of test port when the pneumatic poppers were operated. After popper firing and during the control replicates alewife congregated in the test area. Commercial divers indicated that the net was fully deployed and capable of collecting fish. The divers also observed schools of alewife in the vicinity of the skimmer wall and port.

Current measurements indicated the flow was 14 cm/s in front of the skimmer wall port. Normal water flow 5 m below the water surface in the vicinity of the skimmer wall port is greater than 30 cm/s with all CCW pumps operating (Christie, 1981). All reactor units were shutdown at Pickering NGS 'A' during the test period and only 1 CCW pump was operating. Tests were therefore postponed until water flows increased at the skimmer and fish abundance was

considered adequate for experimental purposes. Neither condition was met during the study period. Therefore further skimmer wall tests were not conducted.

2. CCW Pump Well

Approximately 400-500 alewife were present in the screenwell surface waters during equipment setup at Pickering GS 'B' during June (visual observation). The alewife immediately left the proximity of the poppers when the poppers were test fired. Poor light conditions (only surface water illuminated), turbulence (bubbles released from poppers) and water turbidity in the screenwells prevented observation of the alewife dispersal. However it appeared that some fish descended deeper into the well. Alewife were observed back in screenwells within 5 minutes of the last detonation. The travelling screens operated on automatic cycle during this period. Very few fish were observed to accumulate in the trash bins. Alewife comprised the majority of fish in the bins (estimated 99%).

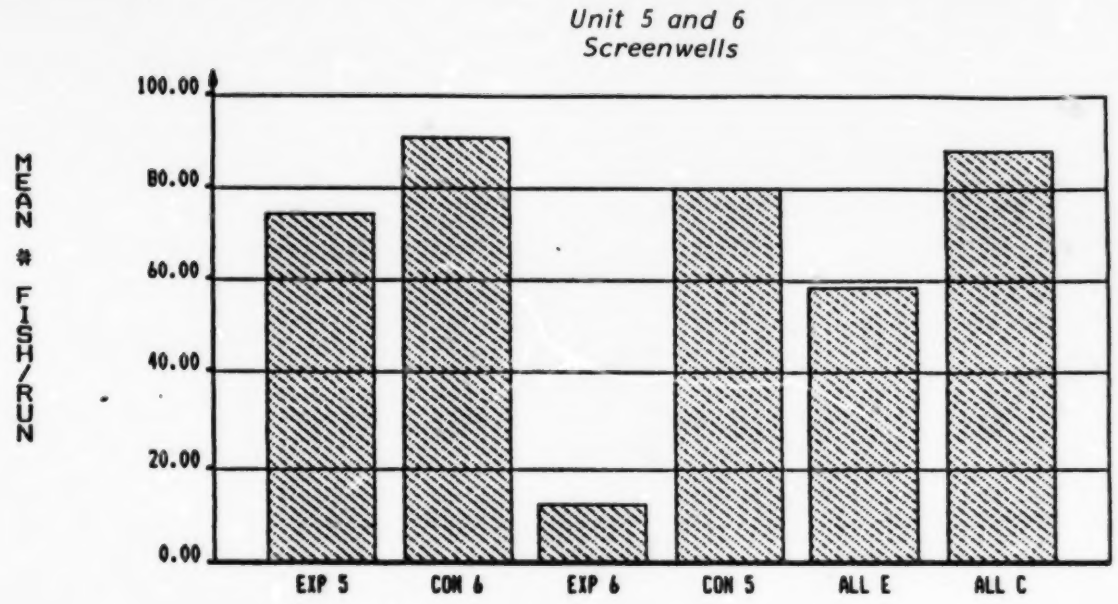
The screenwell popper tests at Nanticoke TGS were performed in November and December (Appendix B). Initial tests using Unit 5 as the experimental and Unit 6 as the control indicated no significant differences ($P < 0.05$) between fish catches within the two screen wells (ANOVA). Fish catches tended to be greater in Unit 6 ($\bar{x}$ = 91.4 fish) than in Unit 5 ($\bar{x}$ = 74.5 fish) (Figure 3.1-1). However, the control fish catches were greater than the experimental fish catches on only 4 of the 17 tests. The control fish catches were influenced by 1 major fish catch (n = 725 fish) approximately 3 times greater than the experimental catch during the first replicate on November 21.

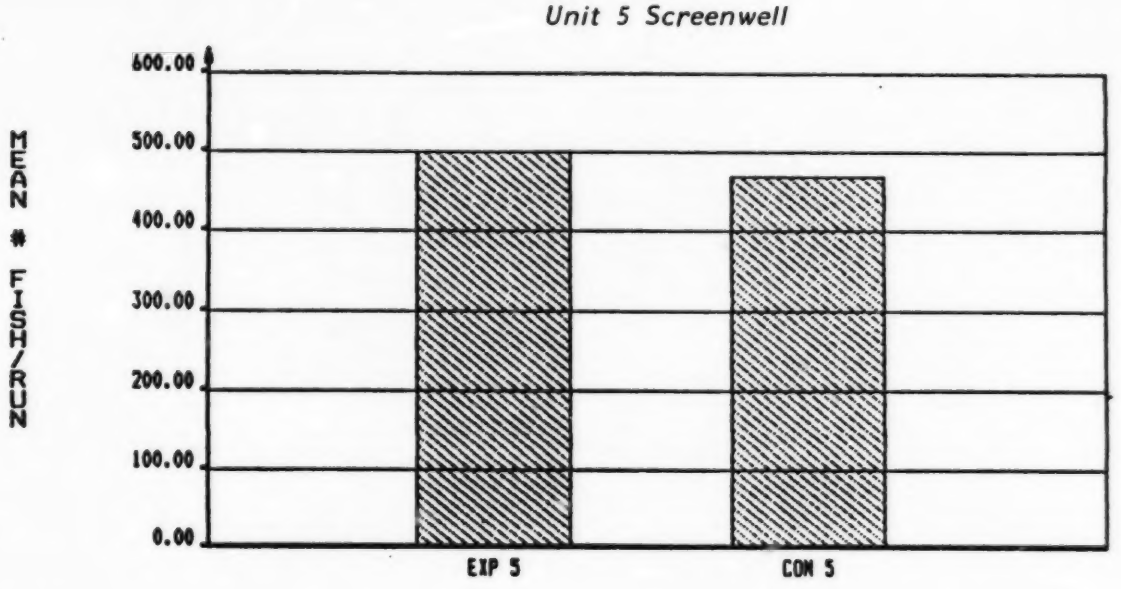
Tests with Unit 6 as the experimental and Unit 5 as the control indicated significantly greater catches in Unit 5 ($\bar{x}$ = 80.0 fish) than in Unit 6 ($\bar{x}$ = 12.5 fish). The control catch exceeded the experimental catch in all 6 replicates (Figure 3.1-1).

The variation between combined Unit 5 and Unit 6 experimental replicates and combined Unit 6 and Unit 5 control replicates was not significant although the mean fish catch was greater in the control replicates ($\bar{x}$ = 88.4 fish) than the experimental replicates ($\bar{x}$ = 58.3 fish). Temporal variation in the catch was not significant in any of the test configurations.

Popper effectiveness appeared to increase when fish abundance increased in the screenwells. Control catches were greater than the experimental catches on 5 of the 7 occasions when fish numbers exceeded 100 fish/screen. However analysis (ANOVA) of all replicates where fish catch exceeded 100 fish/screen did not indicate any significant variation between experimental and control catches.

The individual fish catch results for the 3 dominant fish species (rainbow smelt, Osmersus mordax, gizzard shad, Dorosoma cepedianum and white bass, Morone chrysops collected on the screens during the tests were compared using ANOVA. No significant differences were determined between individual species catches when Unit 5 was the experimental screenwell. The mean catch per replicate was always greatest during the first replicate (1600 hrs). The temporal variation in catch was significant for white bass. Interaction





EXP - Experimental
C - Control

FIGURE 3.1-1

MEAN NUMBER OF FISH COLLECTED ON TRAVELLING SCREENS WITH AND WITHOUT A PNEUMATIC POPPER, NANTICOKE TGS, 1985

between species and temporal distribution was also only significant for white bass.

Variation in the catch of individual species when Unit 6 was the experimental and Unit 5 the control was significant for smelt but not for gizzard shad or white bass. Temporal variation was not significant for any species. The catch during the first replicate (1600 hrs) was greatest for smelt and white bass. Gizzard shad catches were greatest during the third replicate (1800 hrs).

No significant variation could be determined for smelt, gizzard shad and white bass catches when all experimental and all control replicates were analyzed for each species. The greatest catches of each species occurred during the first test replicate. Temporal variation in the catch of white bass only and the interaction of white bass catch and time were significant.

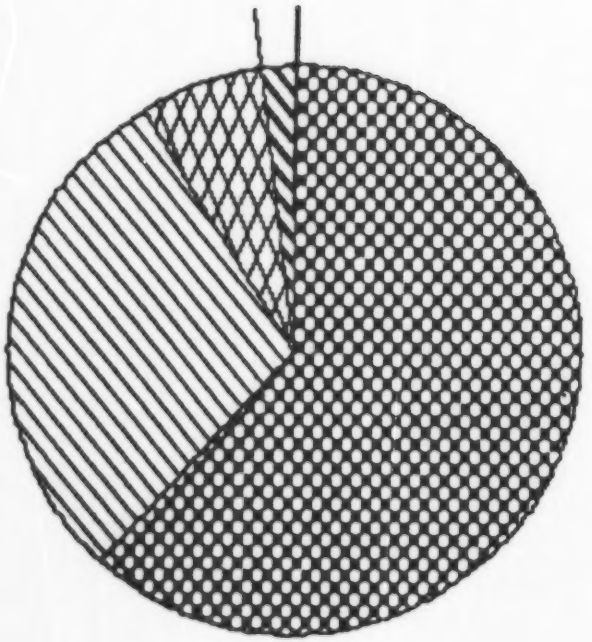
The fish catch results of alternating control and experimental replicates within Unit 5 screenwell indicated greater numbers of fish collected in the experimental replicates ($\bar{x}$ = 501.1 fish) than during the control replicates ($\bar{x}$ = 468.4 fish, Appendix B). Analysis (ANOVA) indicated the variation in fish catch was not significant ($P<0.05$).

3.2 Fish Transfer with Hidrostal Pump

A total of 3004 fish were collected during the 36 one hour pump tests. Juvenile (61.6%) and adult alewife (29.3%, Figure 3.2-1) were the dominant fish collected. Juvenile and young of the year smelt comprised 8.9% of the catch. Only 1 adult smelt was collected. The composition of fish collected in the Hidrostal pump was similar to that in the Pickering NGS 'B' trash bins. Diver observations also indicated a similar dominance of alewife in the forebay near the pump. No fish were collected in the gill net set in the forebay on the night of July 25.

The fish catch results for each Hidrostal pump test configuration are presented in Appendix C. The highest catches ($\bar{x}$ = 150.3 fish/hour) were recorded when the pump was run with the cone light continuously on, an outside light extinguished for 5 minutes at 10 minute intervals and the air bubble curtain on (Configuration F, Figure 3.2-2). The lowest catches ($\bar{x}$ = 42.8 fish/hour) were recorded when the pump was operated alone (configuration A). The variation among test configurations was not significant ($P<0.05$). The variation between the least (configuration A) and most effective (configuration F) configurations was also not significant.

SCUBA diver observations indicated fish were caught in the intake current and drawn into the pump from within a 15 cm distance directly in front of the intake tube and 12.7 cm to the sides. All fish observed entering this area were rapidly drawn into the intake mouth without any signs of resistance. The current reading 15 cm in front of the intake mouth was 1.0 m/s. Current measurements 20 (0.25 m/s) and 46 cm (0.15 m/s) in front of the intake indicated a rapid current decrease. Fish within these areas were able to avoid the pump.



- ALEWIFE JUVENILES	1850.00	(61.6%)
- ALEWIFE ADULTS	879.00	(29.3%)
- SMELT JUVENILES	207.00	(6.9%)
- SMELT ADULTS	1.00	(.0%)
- SMELT YOUNG OF YEAR	59.00	(2.0%)
- BROWN BULLHEAD	1.00	(.0%)
- WHITE SUCKER	2.00	(.1%)
- GIZZARD SHAD YOUNG OF YR	4.00	(.1%)
- SMALLMOUTH BASS	1.00	(.0%)

TOTAL: 3004.00 (100%)

FIGURE 3.2-1
COMPOSITION OF FISH CAUGHT IN THE HIDROSTAL PUMP
DURING NIGHT TESTS, PICKERING NGS, 1985

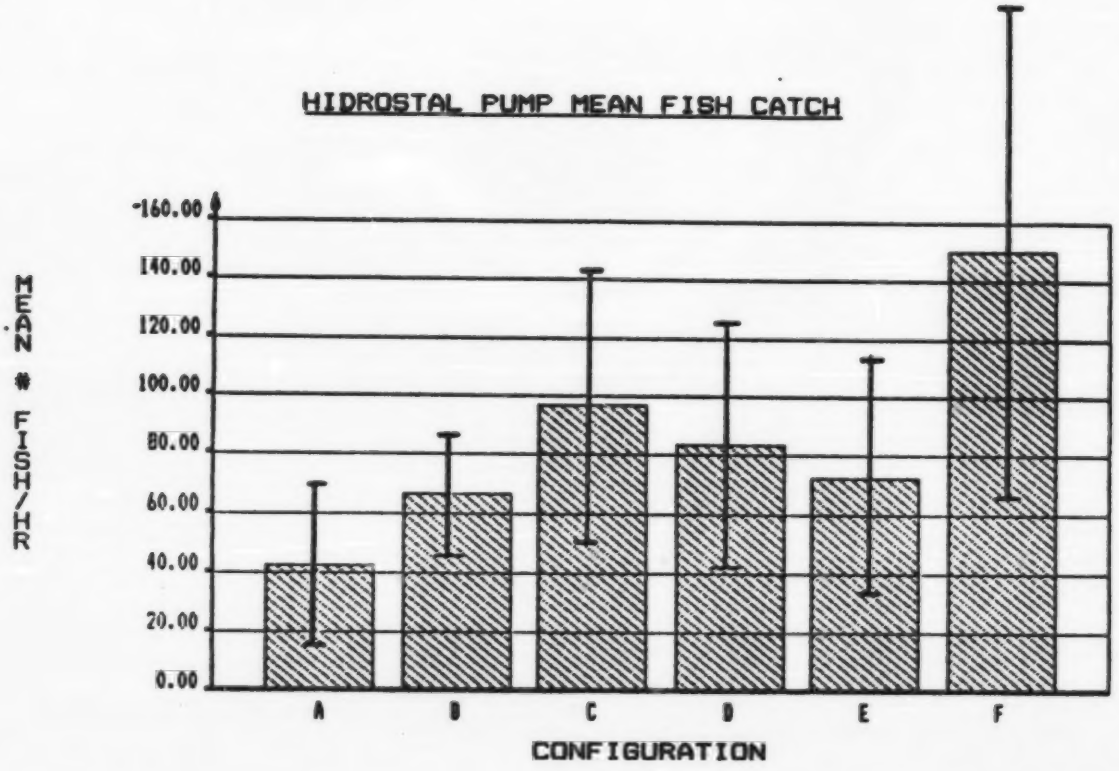


FIGURE 3.2-2
FISH CATCH (MEAN AND STANDARD DEVIATION)
IN THE HIDROSTAL PUMP - PICKERING NGS

Small fish species passing through the Hidrostal pump system generally exhibited no visible damage (5.0 %). Fifteen adult alewife exhibited signs of internal haemoraging primarily around the eyes and fins. Approximately 150 other adult alewife (17.0 % of alewife adults) suffered some scale loss. No damage was detected for juvenile alewife or for all smelt age classes. The incidence of visible damage to larger fish was very pronounced. One white sucker, Catostomas commersoni, (46 cm) exhibited scale loss on the right side between the dorsal and caudal fins while the other white sucker (43 cm) collected received no visible damage. The flesh was removed from the left side of the cranium of the lone 30 cm brown bullhead. Ictalurus nebulosus, collected. No visible damage was apparent on the (18 cm) smallmouth bass, Micropterus dolomieue.

One holding test was conducted with adult alewife and juvenile smelt as the test fish species passed through the pump system. All of the alewife (n = 10) were dead after 16 hours. Each had received slight scale loss during pump transfer. All test smelt (n = 18) survived 16 hours of holding.

Six daylight tests were conducted with the Hidrostal system (Appendix F). Only 32 fish were collected with a maximum catch of 16 fish and a minimum of 0 fish. Alewife was the dominant fish species (n = 29) collected. Damage, primarily scale loss, was evident in 27.5% of the alewife passing through the pump. One 69 cm rainbow trout, Salmo gairdneri, was collected. It received extensive gill damage during passage and died 10 minutes later in the holding tank.

4.0 DISCUSSION

The first objective of the study was to develop an environmental protection system capable of reducing impingement on travelling screens. The pneumatic popper protection system designed for the Pickering NGS 'A' skimmer wall could not be evaluated. All Pickering NGS 'A' units were shut down with either mechanical problems or routine outages and only 1 CCW pump was operating (R. Hester, RMEP Pers. Comm.). Viable fish present in the area of the skimmer wall were therefore not subjected to the normal currents (>30 cm/s) produced by 8 operating CCW pumps and were able to move freely in front of the skimmer wall and ports (visual observation). However, the use of pneumatic poppers to disperse alewife from the vicinity of the skimmer wall appears feasible. Visual observations during tests at the skimmer wall indicated alewife avoided the pneumatic poppers. Results of pneumatic popper experiments in an open lake situation have also indicated significant alewife avoidance with poppers (ESEERCO Report EP-1 83-12). The effectiveness of poppers in diverting fish at the skimmer wall should be assessed when Pickering NGS 'A' returns to normal operation.

The pneumatic poppers operated outside the Nanticoke CCW screenwells did not significantly reduce the number of fish collected on the travelling screens under all test conditions. There are several possible reasons for this. Fish abundance within the control and experimental screenwells was unknown. Differential fish abundance as well as popper influence may therefore account for variation within fish catch. Tests conducted with the control and experimental replicates in the same screenwell were also affected by variation in fish abundance. Fish were removed on the travelling screens and fish

movement in or out of the screenwell was not physically restricted. Alternating the control and experimental replicates, however, may have reduced the influence of fish removal and recruitment.

Avoidance of the popper by fish already in the screenwell may have increased the catch on the travelling screens during popper tests. Open lake tests of the poppers excluded offshore as well as onshore moving fish from the experimental structures (ESEERCO Report EP-1 83-12).

The second study objective was to develop a system capable of attracting and transporting forebay entrapped fish back to the lake in a viable condition. The present study results indicated the potential for an attraction system to guide fish to a pump intake, the potential for fish capture and transport and the problems associated with the attraction and pump systems.

Fish capture can be enhanced with attraction systems. The three most effective attraction configurations tested utilized the cone and outside mercury vapour lights. The use of these lights in conjunction with an air bubble curtain proved to be the most effective configuration. Test results indicated no signficant variation in fish catch between pump alone tests and the tested attraction systems. Previous laboratory fish attraction studies indicated significantly improved fish catches when the fish pump was used in conjunction with guidance systems (OHRD Report 83-142-K).

The number of fish passed at night by the 30.5 cm Hidrostal pump was extremely low compared to a similar study at Bruce NGS 'A' (OHRD Report No 85-258-K). Mean fish passage ranged from 42.8 to 150.3 fish/hr. The mean night fish passage with a 12.7 cm Hidrostal pump situated at the east end of the Bruce NGS 'A' forebay was 2816 alewife/hr (OHRD Report 85-258-K). The number of fish in the Bruce forebay in June was estimated to be low to medium. Impingement at Unit 4, closest to the test site, was 1000 kg (approx 25 000 fish) in June. Pickering NGS 'B' fish impingement (3 units) declined from 5500 kg (approx 137 500 fish) in June before testing to 3800 kg (approx 95 000 fish) and 83 kg (approx 2100 fish) in July and August, respectively (R. Hester, RMEP, Pers. Com.). Tests were only conducted in late July and early August during the period of rapid fish decline.

Pump location at each station was different. The Pickering NGS Hidrostal pump test site location was selected on the basis of low current velocity, available work area and access to station facilities. The experiment was designed to test the effectiveness of the attraction systems to incresae fish abundance within the pump intake area. Fish abundance within this area and the Pickering NGS 'B' channel was not known. The Bruce NGS 'A' test site was located in a known fish concentration area. Mercury vapour lights were used to attract these concentrated fish within the effective capture zone around the intake mouth.

The difference in velocities at the pump intake between the Bruce and Pickering studies was considerable. The Bruce intake velocity was 3.8 m/s with an effective capture distance of 15-20 cm from the intake mouth (B. Sim, Pers. Com.). The maximum intake velocity attainable during the Pickering study was 1.0 m/s with an effective capture distance of 15 cm. The Bruce Hidrostal pump, operated at 850 RPM delivering approximately 4200 L/min (15 cm

diameter intake). The Pickering pump operated at 600 RPM delivering approximately 6600 L/min (15 cm square intake). Operation at greater speeds collapsed the intake pipe (1.6 kg/sq cm working pressure at 22°C) and caused the pump to cavitate. The vacuum related cavitation and pump starvation problems resulted from reducing the pump intake from a 30.5 cm diameter to 15 cm square to increase the intake velocity and effective capture zone. Pipe collapse could be eliminated by using solid instead of flexible pipe. This would require accurate system design and construction not required in the experimental design. The cavitation problem can be solved by decreasing the pump speed with a resultant loss of intake velocity or reducing the discharge head. Reduction of the discharge head would permit the pump to be run at higher RPM producing a greater intake velocity. The maximum RPM level would still be limited by the cavitation point. Operation of the pump at the cavitation point is not efficient and could subject fish to substantial pressure changes.

The Bruce study was designed to determine the optimum intake configuration to maximize fish capture. Repositioning of the intake mouth was required to achieve this. The intake at Pickering was positioned at a fixed location. Maximum fish capture was not a consideration. Test results were based on the effectiveness of each attraction system to lead fish to the intake mouth for pump passage.

Fish escapement from within the effective current zone (15 cm) surrounding the inlet mouth of the Pickering pump is not known. The intake mouth was not observed on a regular basis. However SCUBA divers did not observe alewife escape while observing the intake. The estimated maximum swimming speed for fish species is approximately 5 to 6 body lengths per second (A.E. Christie, Pers. Com.). The calculated maximum swimming speed for an average (15.2 cm, Scott and Crossman, 1973) adult alewife may have avoided the intake current. Larger fish species (rainbow trout, smallmouth bass, brown bullhead and white sucker) with potentially greater maximum swimming speeds were collected by the pump. These fish may not have been able to perceive and respond to the rapidly increasing intake current before they were transported. Operation of the pump at 800-900 RPM would increase the intake velocity and reduce the possibility of fish escape from within the effective zone.

Fish catch may also have been influenced by the fouling (silt and organic growth) of the clear acrylic intake pipe and the mercury vapour light lenses at Pickering. The pipe and lenses required cleaning every 2 days. Significant alewife avoidance of an opaque intake was demonstrated during the Bruce study and may have occurred at Pickering. Fouling of the mercury vapour light lenses would reduce their effective attraction range. Any permanent attraction and transfer system constructed in an area where fouling by silt or algal growth is probable must incorporate a cleaning system in the design to maintain attraction and capture efficiency.

The air bubble wand was covered by silt within 1 month of setting and required resetting after extended periods of nonuse (2 months). The air pressure within the bubble curtain system was insufficient to clear all of the silt overburden and ensure a continuous bubble curtain when restarted. Any permanent bubble curtain system should be designed with the air line extending the entire length of the bubble curtain. Air ports would lead from the air

line to the bubble wand at wand junction points. This system would equalize the air pressure along the entire wand system providing a consistent bubble curtain. The bubble curtain system should only be used in areas where siltation is not a problem unless the system can be designed for continuous operation or with sufficient air pressure to clear the silt overburden. Previous studies at Nanticoke TGS indicated the use of bubble curtains in high current areas was not feasible (OHRD Report 84-310-K).

The overall incidence of fish damage (5%) in the Pickering study was similar to the Bruce study results (<5%). Similarly the incidence of injury was greater in fish larger than 15 cm in length at both Pickering (60%) and Bruce (30%). Lower injury rates were expected for larger fish species passed through the 305 cm diameter Hidrostal pump (Christie, 1978). The higher injury rate may be related to the low sample size (n = 5) and the operation of the pump above maximum efficiency.

5.0 CONCLUSIONS

Although abnormally low current flow at the skimmer wall prevented evaluation of the pneumatic poppers, prior field and laboratory studies and visual observations of popper avoidance at the wall indicated the potential of the poppers to divert fish. The present experimental design would be satisfactory for popper evaluation studies.

The use of poppers outside of CCW pump screenwells was not successful in significantly reducing fish impingement.

Fish attraction systems can increase the number of fish in the vicinity of the Hidrostal pump's effective current zone. The increase in transported fish was not significant during the present study. However, the study was conducted during a period of declining fish stocks. The intake mouth and immediate area outside the intake should be illuminated with filtered mercury vapour light. The use of a bubble curtain in conjunction with the lights will probably increase fish catch in forebays with low current and siltation rates.

The Hidrostal pump was operated above optimum efficiency to maintain an intake velocity greater than the swimming speed of alewife. Permanent pump installations should be operated at optimum efficiency. This can be achieved by reducing the discharge head.

The alewife injury rate was similar to field studies with smaller pumps. The injury rate of incidental fish species was higher. This may be due to operation of the pump above peak efficiency. The choice between small or large diameter intake pumps must be decided primarily on their performance characteristics. Injury rate to incidental larger fish species should be a secondary concern.

6.0 RECOMMENDATIONS

The efficiency of pneumatic poppers in diverting fish from the Pickering NGS 'A' skimmer wall should be evaluated during the major period of fish impingement with all units operational.

Pneumatic poppers are not recommended for use outside of the CCW pump screenwells.

Establishment of a permanent fish attraction and transfer system at stations with high impingement rates is recommended. Fish pump selection should be based on pump performance characteristics for each location. The intakes should be composed of clear material with a minimum opening of 15 cm diameter. The intake should be illuminated inside and outside by filtered mercury vapour lights. A bubble curtain angled across the forebay to the pump intake should be installed when feasible.

All permanent installations must incorporate systems permitting frequent clearing of fouled equipment.

A permanent pump intake should be located in an area of known fish concentration to maximize fish transfer and impingement reduction.

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APPENDIX A

HIDROSTAL TRANSFER SYSTEM SCHEDULE

PICKERING NGS, 1984-1985

Date	Event	Remarks
October 22-26	Hidrostal Pump Transfer System Set Up	Required Electrical Hookup
November 26-30	Electrical Power Supply Hooked Up	Power Turned Off Until Operation Memo Issued By Pickering
	Pump Tested	Discharge Hose Blown Off Pump
	Discharge Pipe Adaptor Constructed and Installed	
December 10-14	Power Turned On December 12	
	Discharge Hose Blew Off Pump After Running 10 Minutes	
	Retrofit Discharge Hose Assembly Install New Intake Cone (10 x 10)	Old Cone Fouled With Algal Growth
December 17	Discharge Hose Split and Intake Hose Collapsed After Running Pump for 20 Minutes	Supplier Believed Hose Adequate for Job
December 18	Intake and Discharge Pipes Dismantled	
February 4	Repaired Hoses and Pump Fittings Installed	
	Pump Tested for 30 Minutes Without Failure	
Feb 25-March 1	Discharge Hose Blew Off Pump	Hose Reinstalled with Heavier Clamps and Screws
	Discharge Hose Blew Off Again	Hose Repaired
	Intake Hose Collapsed	Hose Repaired
	Pool Liner Separated From Sides After Running Pump for 30 Minutes	

Date	Event	Remarks
March 4-8	Pool Damaged During Ice Storm	
	Fish Tank Obtained from Bruce GS'A' and RMEP	
	Tank Installed in Place of Pool	
March 11-15	Adapted Discharge Hose Assembly to Tank Configuration	
	Discharge Hose Split After 30 minutes	Supplier Contacted - Hose Appropriate for Needs
	New Pipe Installed	
March 18-22	Hose Blew Off Pump After 10 Minutes	Tests Terminated
April	Hi Pressure Hose Ordered For Discharge Connections	
June 10-14	Hi Pressure Hose Installed Intake Hose Realigned Plexiglass Pipe Cleaned	
	Electrical Power Supply Not Functioning	Pickering Electricians Servicing System
June 17-21	Power Supply Repaired	
	Breakers Blew 3 Times in a Row When Pump Turned On	Pump Repairman Called In
	Solenoid Relief Valve Faulty	New Part Ordered
	Repairman Believed System Not Capable of Delivering Required Water Volume to Tank on Top of Groyne with Present Hydraulic and Electric Motor Capacities	Supplier Was Contacted-He Stated System was Capable of Delivering Water Volume as Set Up - Later Said System Was Not Designed for Present Set Up
June 24-28	Arrangements Made to Move Tank	
	New Cradle Built to Northeast of Original Pool Site Closer to Lake Level	
July 1-5	No Crane Available to Move Tank	

Date	Event	Remarks
July 8-12	Tank Positioned on Cradle	
	Discharge Pipes Assembled Installed New Relief Valve Pump Tested	
July 15-19	Drain Pipe Installed From Tank Back to Forebay Ran Tests Installed 15 cm Square Intake Reducer As Recommended Meeting July 3	
	Intake Pipe Collapsed When Pump Run 5 Minutes at 800 PSI	
July 22-Aug 2	Installed New Intake Pipe	
	Ran Pump Experiments at 600 PSI With No Further Breakdowns	

APPENDIX B

FISH CATCHES - SCREENWELL POPPER TESTS
NANTICOKE TGS - 1985

		Expermimental (Units)							Control (Unit 6)						
Date	Time	FWD	WB	SMT	GZS	YP	OTH	TOTAL	FWD	WB	SMT	GZS	YP	OTH	Total
11/13	16:15	1	6					7	1	14	16				31
	17:15		1	15	3			19		1	1				2
	18:15		3	19				22			2				2
	19:15		3	22		1		26		2	3				5
	20:15	1	6	11				18		2	4				6
	21:15		2	11			1	14		2	3				5
11/14	16:00		2	66				68		19	7				26
	17:00		1	22	2			25							0
	18:00	1	2	19				22							0
	19:00			18				18			1				1
	20:00			16			1	17			1				1
	21:00		3	19				22		3	1	2	1		7
11/21	16:00		3	228	8	1	3	243		11	580	91		43	725
	17:00		1	64	2	1		68		1	153	14		5	173
	18:00		4	222	11	1	6	244		2	165	11		12	190
	19:00		6	271	7		7	291		4	179	43		9	235
	20:00		4	133	3		3	143		4	120	10	1	9	144

		Experimental (Unit 6)							Control (Unit 5)						
Date	Time	FWD	WB	SMT	GZS	YP	OTH	TOTAL	FWD	WB	SMT	GZS	YP	OTH	Total
11/18	16:00		12	18	7		4	41		30	150				180
	17:00			1				1			31	2		1	34
	18:00		3	6	2			11		6	82	14		1	103
	19:00		1	4				5			71	9	1	2	83
	20:00			7	2			9			28	2	1	2	33

		Experimental (Units)							Control (Units)						
Date	Time	FWD	WB	SMT	GZS	YP	OTH	TOTAL	FWD	WB	SMT	GZS	YP	OTH	Total
11/19			2	47	3	4	2	58		1	31	4		1	37
			1	30	2			33		1	29	2		1	33
			1	20	2			23							
11/20			7	211	15		6	239		3	79	4		3	89
			1	103	6	1		111		2	83	4	1		90
			14	239	13	2	3	271							
12/03				1172	24	1	51	1248		2	810	19	3	6	840
				1651	37	9	99	1796		15	1484	54		72	1625

FWD - Freshwater Drum FWD - Freshwater Drum SMT - Smelt GZS - Gizzard Shad
Shad YP - Yellow Perch OTH - Other (Stone Cat, Rock Bass, Emerald Shiner, Walleye, Spottail Shiner, Pumpkinseed, Trout Perch)

APPENDIX C

HIDROSTAL PUMP CATCHES - PICKERING NGS 1985

Test	Date	Time	Temp °C	Turbidity (NTU)	Alewife			Other[1]	Total
					Juvenile	Adult	Total		
A	07/22	01:00	17.0	0.75	4	10	14		14
A	07/23	02:35	7.0	0.81	5	8	13		13
A	07/24	00:08	9.0	1.10	9	50	59	1	60
A	07/29	22:30	15.0	1.40	135	23	158	9	167
A	08/06	00:05	23.0	--					0
A	08/06	23:10	22.5	2.00	3		3		3
B	07/22	02:20	17.0	0.75	35	53	88	5	93
B	07/23	03:40	7.0	0.76	7	16	23		23
B	07/24	01:55	9.0	0.90	18	96	114	2	116
B	07/29	23:40	15.0	1.40	73	21	94	10	104
B	07/30	23:30	18.0	--	32	10	42	1	43
B	08/06	01:15	23.0	--		4	4	19	23
C	07/22	03:35	15.0	0.75	160	134	294	27	321
C	07/23	04:50	7.0	0.76	39	9	48		48
C	07/24	03:00	8.0	0.90	21	4	25	32	57
C	07/30	00:50	15.0	1.40	33	18	51	3	54
C	07/31	00:40	19.0		43	31	74	4	78
C	07/31	23:35	18.0	1.00	2		2	21	23
D	07/22	22:35	9.0	0.81	186	72	258	9	267
D	07/24	04:15	8.0	0.90		10	10	18	28
D	07/30	02:00	15.0		186	4	15	3	18
D	07/31	01:50	17.0		118	4	129	3	132
D	08/02	00:10	18.0	1.10		3	3	4	7
D	08/06	02:25	23.0	1.80		1	1	46	47
E	07/23	00:00	9.0	0.81	174	82	256	11	267
E	07/23	22:40	11.0	1.10	5	37	42	2	44
E	07/30	03:10	14.0		17	15	32	3	35
E	07/31	03:00	17.0		5	8	13	3	16
E	08/06	03:35	23.0	1.80	8		8	3	11
E	08/07	00:20	22.5	2.00	51	2	53	10	63
F	07/23	01:00	9.0	0.81	471	63	534	14	548
F	07/23	23:45	11.0	1.10	18	49	67	9	73
F	07/30	04:20	14.0	1.30	60	12	72	3	75
F	07/31	04:10	17.0	1.00	26	4	30	3	33
F	08/06	04:45	23.0	1.80	59		59	1	60
F	08/07	01:30	22.5	2.00	87	5	92	21	113
A	07/16	11:15	10.7			10	10	1	11
A	07/17	11:25	7.0			1	1		1
B	07/16	12:30	10.7			1	1		1
B	07/17	12:30	7.0						0
C	07/16	13:35	10.7		7		15	1	16
D	07/17	08:55	7.0			2	2	1	3

[1] Other-primarily smelt plus 1 rainbow trout, 2 white sucker, 1 smallmouth bass, 1 brown bullhead and 4 gizzard shad

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